Homestake Interim Laboratory & Homestake DUSEL: Summary for P5

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A Golden Opportunity for Science

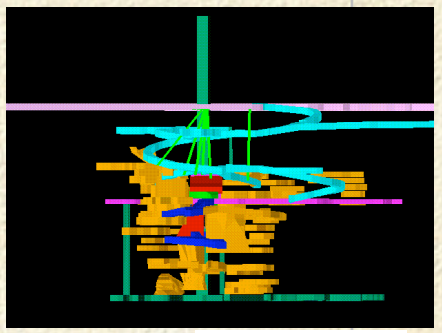
Outline

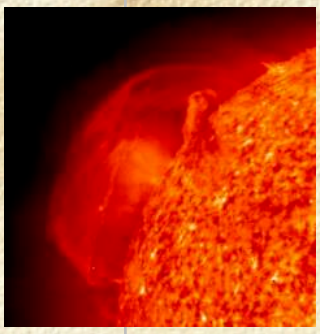
1. DUSEL Science Drivers - Overview
2. The Homestake Facility, History & Ownership
3. Homestake's Early Implementation Program, Initial Suite of Experiments, and Phased Approach to Science
    1. Homestake's Physics Program
4. Summary

1) DUSEL the Big Picture

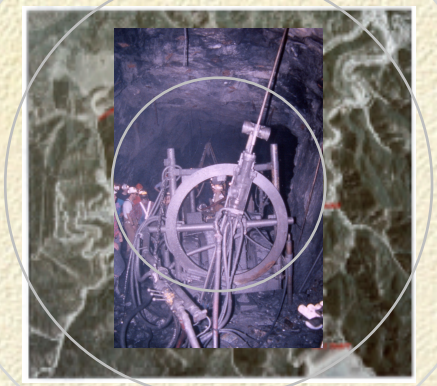
Dark Matter
Cosmology
Astrophysics
Neutron Oscillation

Geo-Database
Geo Modeling
Geophysics
Seismology
Fracture Study

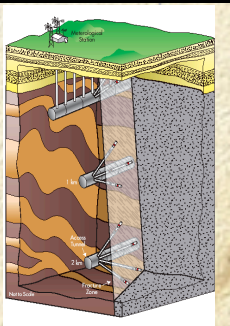


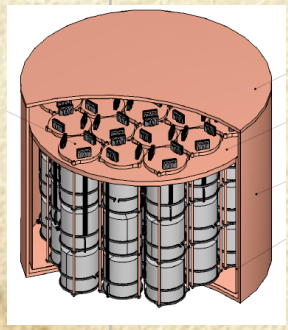


Solar Neutrinos
Geoneutrinos
Underground
Accelerator for
Astrophysics
Gravity Waves

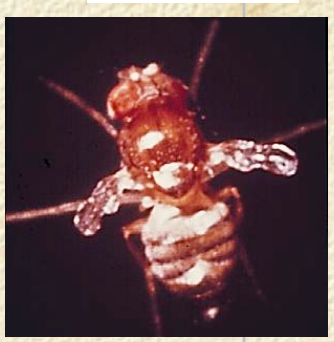


Cloud Formation
Lightning Physics
Thermal History
Coupled Processes
Rock Mechanics
Hydrology
Mineral Studies
Economic Geology

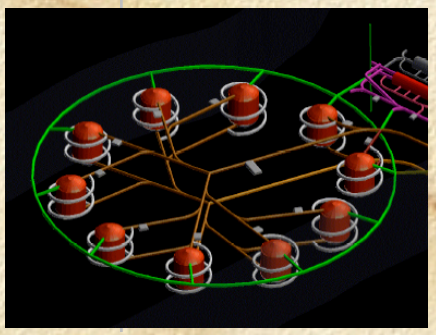




$o\nu\beta\beta$
Neutrino Properties
U/G Manufacturing
Low Background Counting



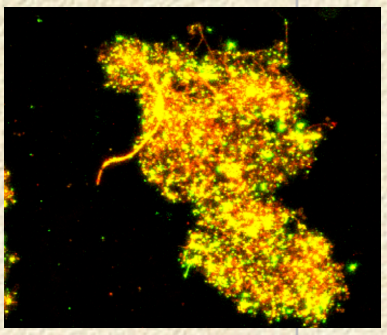
Geomicrobiology
Bioprospecting
Life at Extreme
Conditions



Neutrino Properties
Long-baseline ν Oscillation
CP violation
MNSP Matrix
Nucleon Decay
Atmospheric Neutrinos

Underground
Engineering
Homeland Security

Geochemistry
Ecology
Environmental
Studies

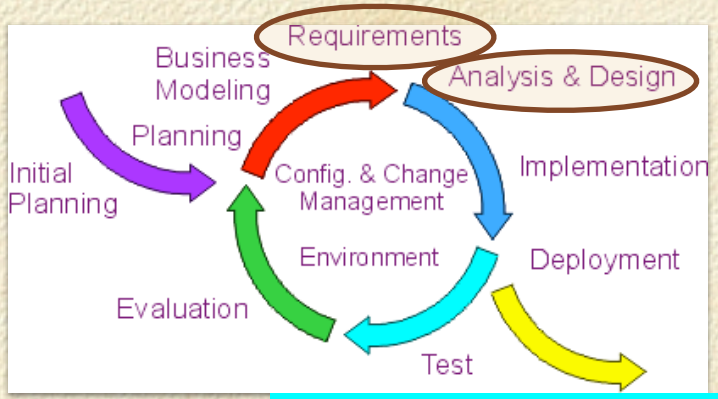


Education & Outreach

2) Homestake Facility, History, and Ownership

Homestake Strategies: 4850-lab ➢ DUSEL

- Union of Efforts Working on the Homestake Laboratory
  - Homestake Collaboration Developing the NSF solicitation process responses: S-1, S-2 (CDR), *S-3 (TDR)*, establishing scientific roadmaps and expanding the network of potential users and uses.
  - South Dakota Science and Technology Authority (SDSTA) working with South Dakota resources to preserve Homestake for DUSEL and establishing an interim laboratory option



Initial Uses in 2007

Expanded Uses in 2009 as DUSEL

Homestake History and Progress in Establishing Interim Facility

- 2001 Homestake selected by the Bahcall Committee: fastest time to science and lower capital outlay, strong beneficial impact on local community, lower risks

  - 2002 Nobel Prize awarded to Davis for his Chlorine Experiment at Homestake's 4850 level.

- Homestake was again selected in May 2003 by the NSF as the prime site for DUSEL by an independent panel siting report
- Spring 2003 Barrick closed, capped and sealed Homestake:
  - Clean up and and closure documented by EPA
  - Mothballed surface equipment, preserved spares
  - Ventilation of the mine altered to preserve infrastructure
  - Pumping ceased, water started accumulating in the mine, *currently ~ 6200 level (Jan 2006), in flow ~ 700 g/m (⅔ above 5000L)*

- Jan 2004, “Agreement in Principle” between Barrick and SDSTA to transfer Homestake
- Feb 2004, South Dakota legislature enacts legislation to effectuate the transfer and satisfy “Agreement” provisions
  - Created Authority with $100M bonding ability
  - Enacted State Indemnity and Immunity Statutes
  - Funded $14.3M (+ $10M from HUD action)
- March 2004, New NSF 3-step process
- Dec 2004, SDSTA Conversion Plan Vetted, 4850 Lab concept developed
- Feb 2005 Barrick confirms 4850 Lab satisfies the “Agreement”
- September 2005, “Agreement” with Barrick amended to conform to 4850 lab, water permits renewed by Barrick

- October 2005, State Legislature approves additional $20M funding for Homestake, total of $46M from state controlled sources.
  Rehab plan: $15M, Indemnification fund: $10M, Operations: $15M (initialization + 5 years of EIP), Contingency: $3.5M, Insurance: $2.5M
- 1 November 2005 - First call for *Letters of Interest* for Homestake
  ~ 85 letters received by February 2006
- December 2005 - two workshops at AGU in S.F. & Town Meeting
- 9 February 2006 - Physics and E&O workshops Lead, ~ 135 attendees
- 10 - 11 February 2006 - 1st PAC meeting for Homestake, LOIs present written documents and oral presentations to the PAC
- April 2006 - PAC report

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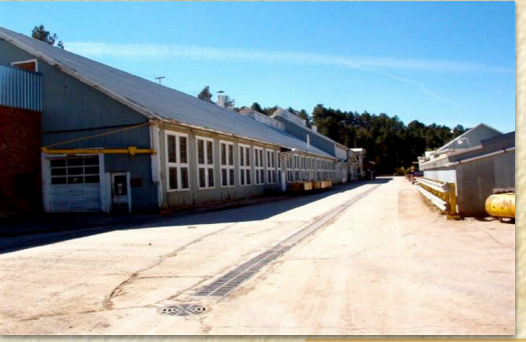
SDSTA's Landlord Role

- To preserve Homestake for DUSEL: *State Funded Plan*
- Rehabilitation plans were established and vetted 2004:
  - obtain title to the facility
  - establish access to the facility and the underground
    - refurbish lifts, shafts, drifts
  - deal with the water (remove upper inflow, hold at 5300)
  - establish interim facility 4850L, 300L, operate ~ 5 years
- Opportunities for early science uses and establish a path to evolve Homestake into a national facility

Status of Property Transfer

- [x] Survey and plats completed and approved
- [x] Property Donation Agreement **Completed**
  14 April 2006, Property open end of May 2006
  - [ ] Original document: no precedence
  - [ ] Many parties involved and many *needs*
  - [ ] Very complicated
  - [ ] Must be accurate and **enduring**
- [x] Shared use agreement is completed



SDSTA Actions Following Signing of Agreement

- Close and transfer possession within 45 days of signing agreement - **end of May 2006**
- Ownership and Legal/Liabilities issues completed
  - **Hire Staff** with Homestake experience
    - Safety officer, Mine Rescue, Mine engineer
    - Operations Supervisor, Project Manager, Administrative staff …
  - Remodel office space
  - Transfer all utilities and services

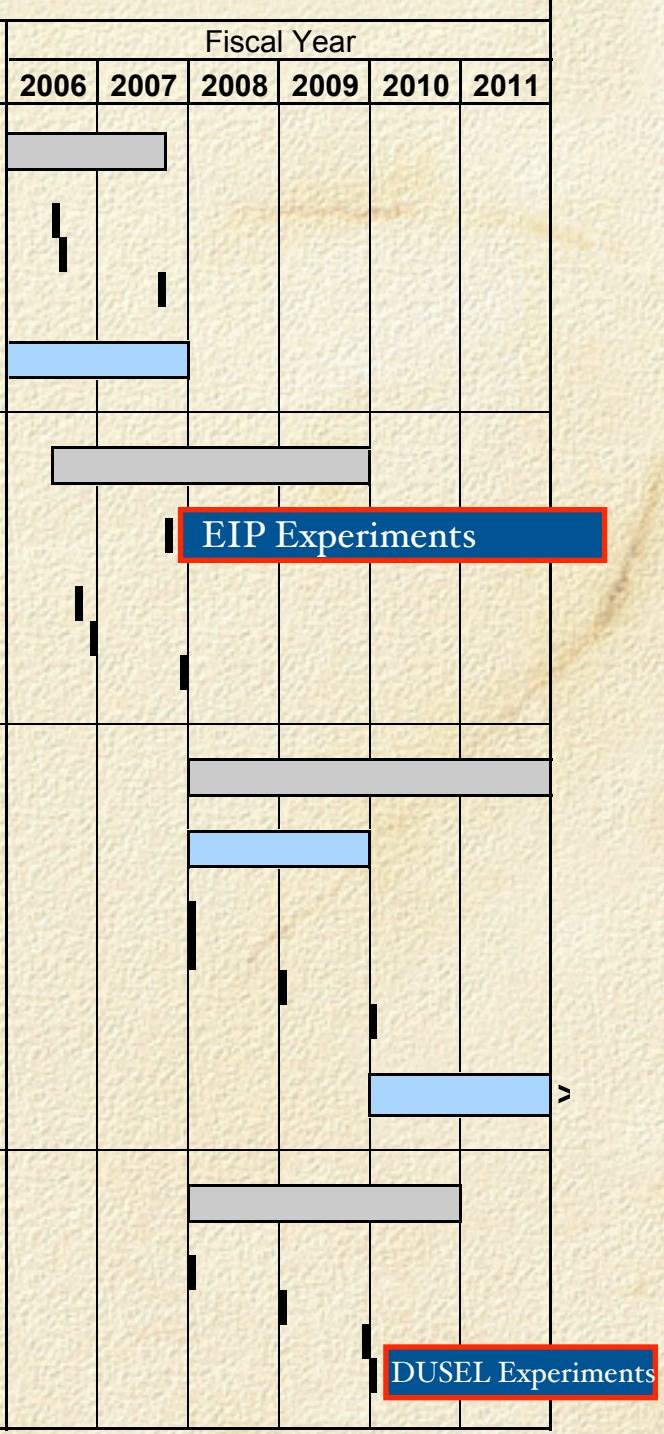
SDSTA Role Following Transfer and Initiation of Interim Facility

- Refine cost estimates of rehabilitation
- Solicit bids for rehabilitation work
- Manage and supervise contracted work
- Incorporate PAC recommendations into EIP
- Design and engineer rehabilitation plan
  - Rehabilitate Hoists, Shafts, Drifts, Utilities
  - Water discharge permits & rock disposal sites
- Development of 4850 Level
  - Support facilities
  - Room enlargement or modification
  - Upgrades as budget permits
- Safe operation of mine & property and infrastructure

Management and Project Execution

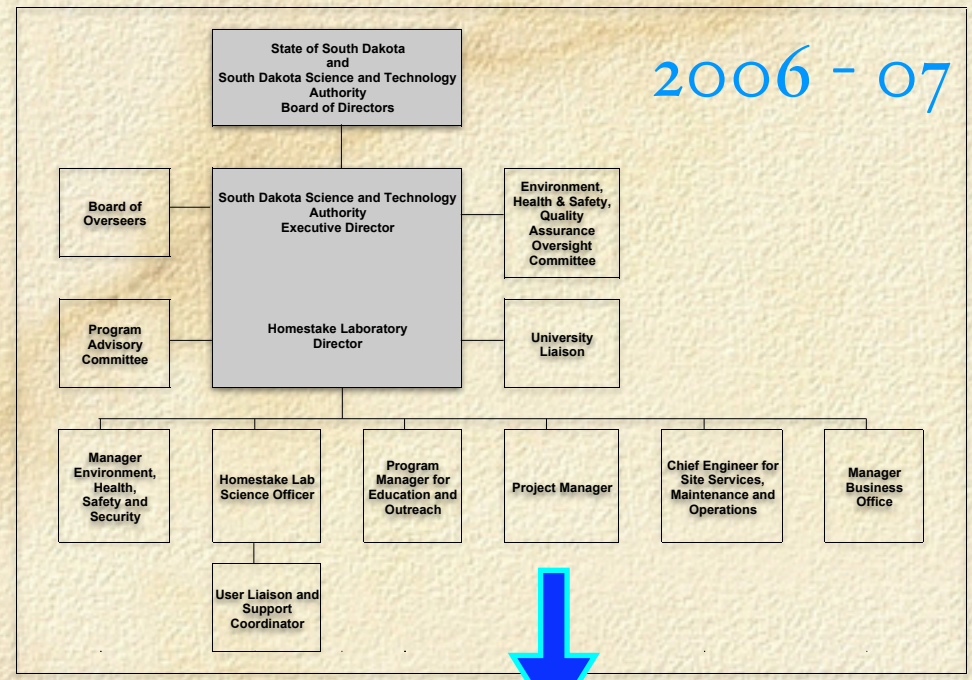
Proposed Homestake DUSEL Project Timeline and Major Milestones

Project Phases (Lead Organization)	Start
Phase 1: Mining-to-Labs Conversion and Re-entry to Mid-Levels	**Oct-05**
(SDSTA)	
Milestone: Homestake Ownership Transfer to SDSTA	**Apr-06**
Milestone: SDSTA Occupancy, Initiate Conversion Project Detailed Engineering	**May-06**
Milestone: Mid Levels Beneficial Occupancy for EIP early experiments	**Jun-07**
Organization Chart: Homestake Lab Interim Management Organization	
Phase 2: Early Implementation Program (EIP) S&E Labs	**Apr-06**
(Berkeley)	
Milestone: Ready to begin Construction & Outfitting for EIP early experiments	**Jul-07**
Milestone: Submit Homestake DUSEL Conceptual Design Report (NSF S-2)	**Jun-06**
Milestone: Homestake Site Selection for DUSEL	**Sep-06**
Milestone: Submit Homestake DUSEL Preliminary Design Package (NSF S-3 TDR)	**Sep-07**
Phase 3: DUSEL Re-entry and Access to Deep Levels	**Oct-07**
(SDSTA)	
Organization Chart: Homestake DUSEL Transitional Project Organization	
Milestone: Begin DUSEL Facility & Systems Detailed Design (NSF Funding)	**Oct-07**
Milestone: Begin Detailed Engineering for Deep Levels Re-entry and Dewatering	**Oct-07**
Milestone: DUSEL Facility Infrastructure Construction Start	**Oct-08**
Milestone: Homestake DUSEL Beneficial Occupancy	**Oct-09**
Organization Chart: Homestake DUSEL Management Organization	
Phase 4: DUSEL Science and Engineering Program Development	**Oct-07**
(Berkeley)	
Milestone: Begin R&D for Initial Suite of Experiments (ISE) (NSF Funding)	**Oct-07**
Milestone: Begin DUSEL ISE Detailed Design	**Oct-08**
Milestone: Submit Detailed Design for DUSEL ISE	**Sep-09**
Milestone: Initiate Construction & Outfitting for DUSEL ISE	**Oct-09**

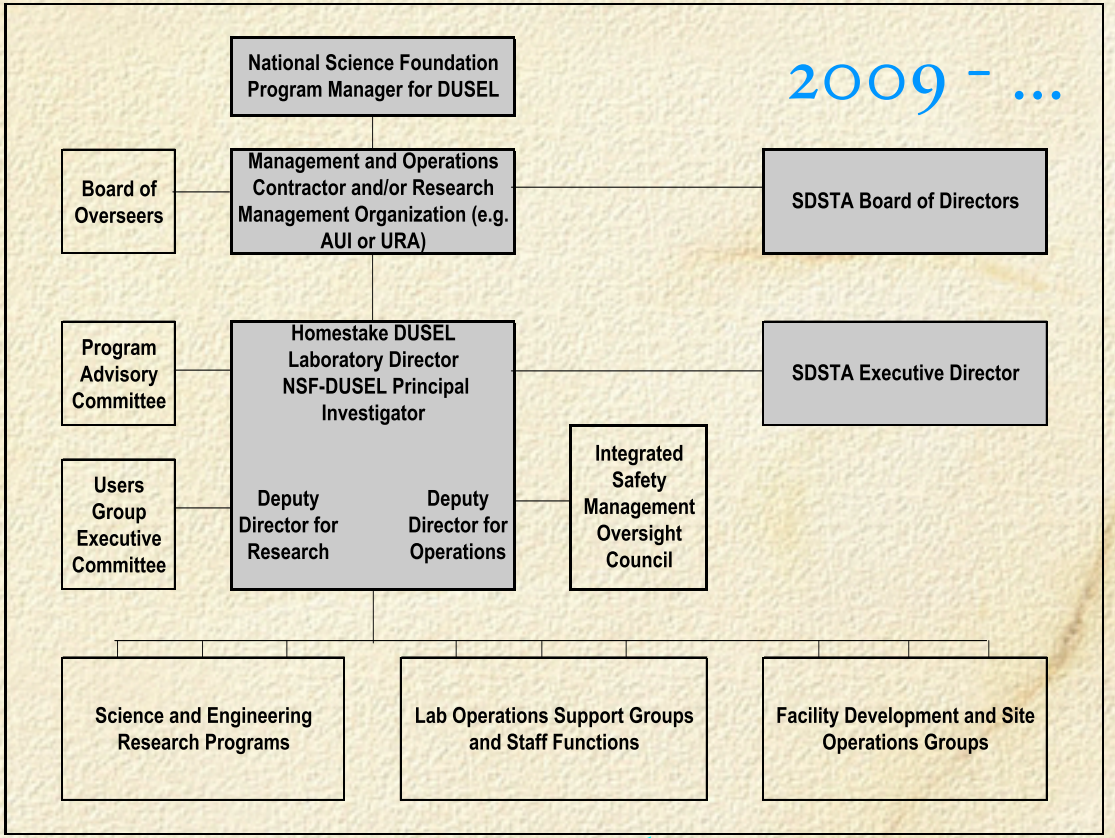


Homestake Management

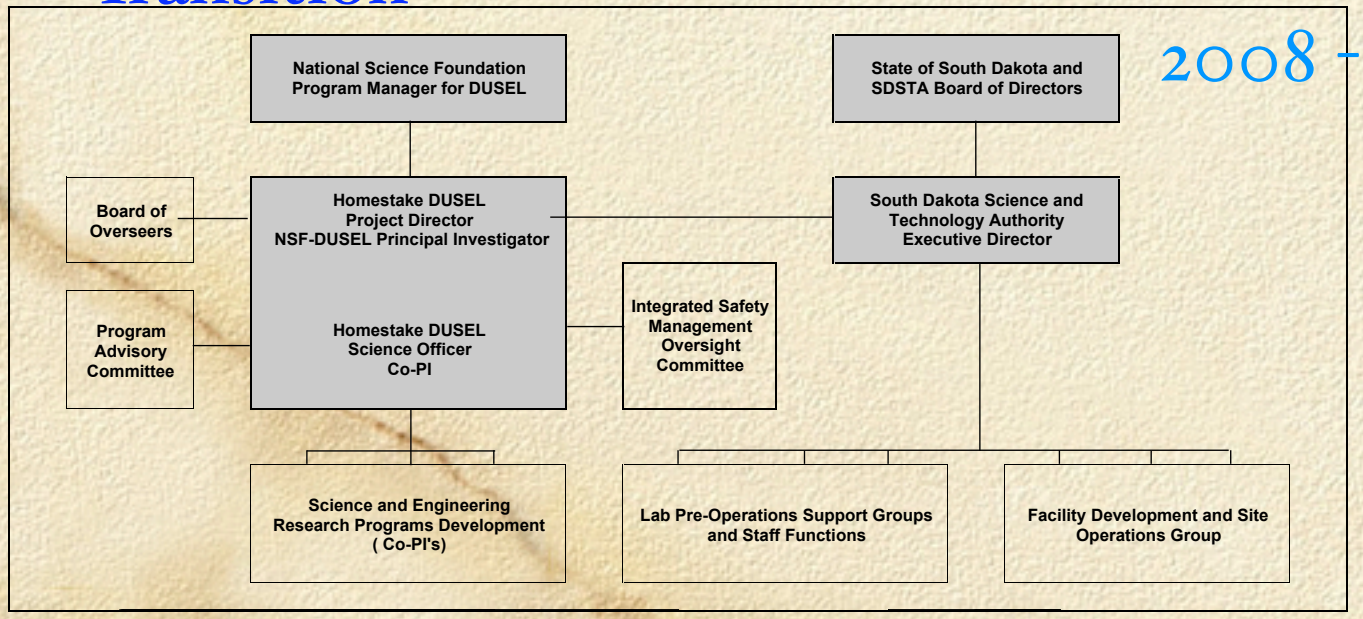
Rehab and Interim Facility



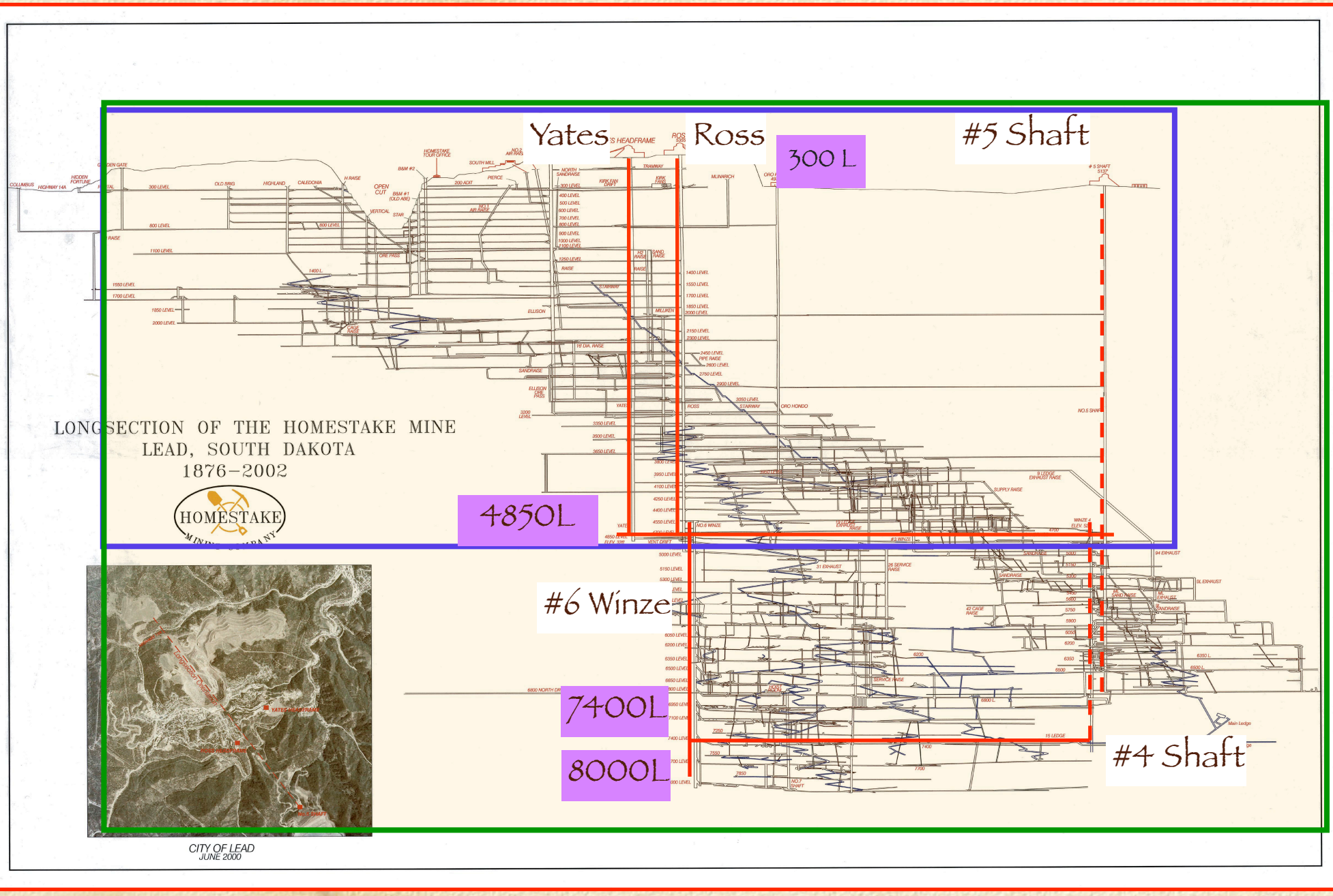
DUSEL



Transition

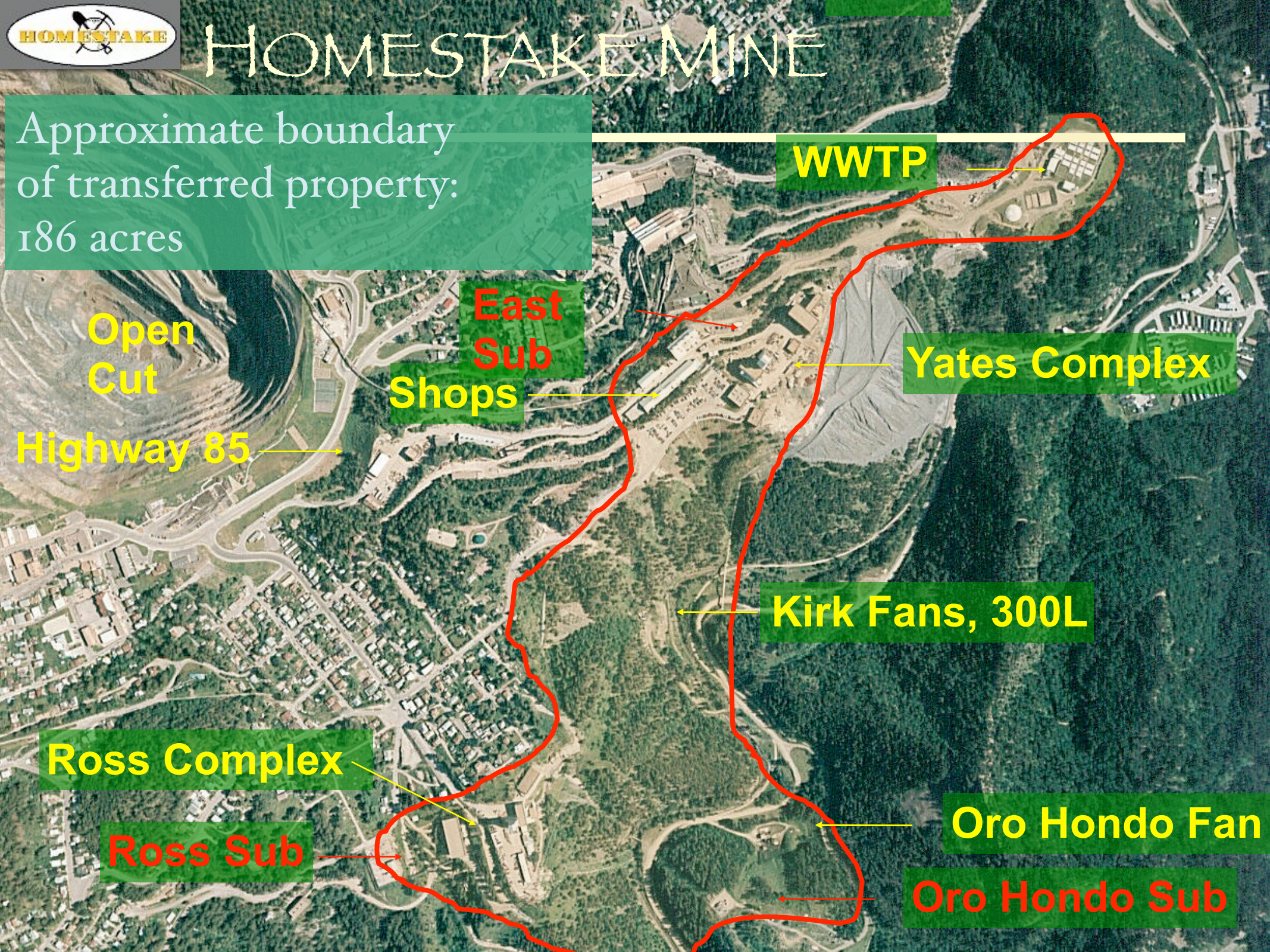


Phased approach to building DUSEL at Homestake



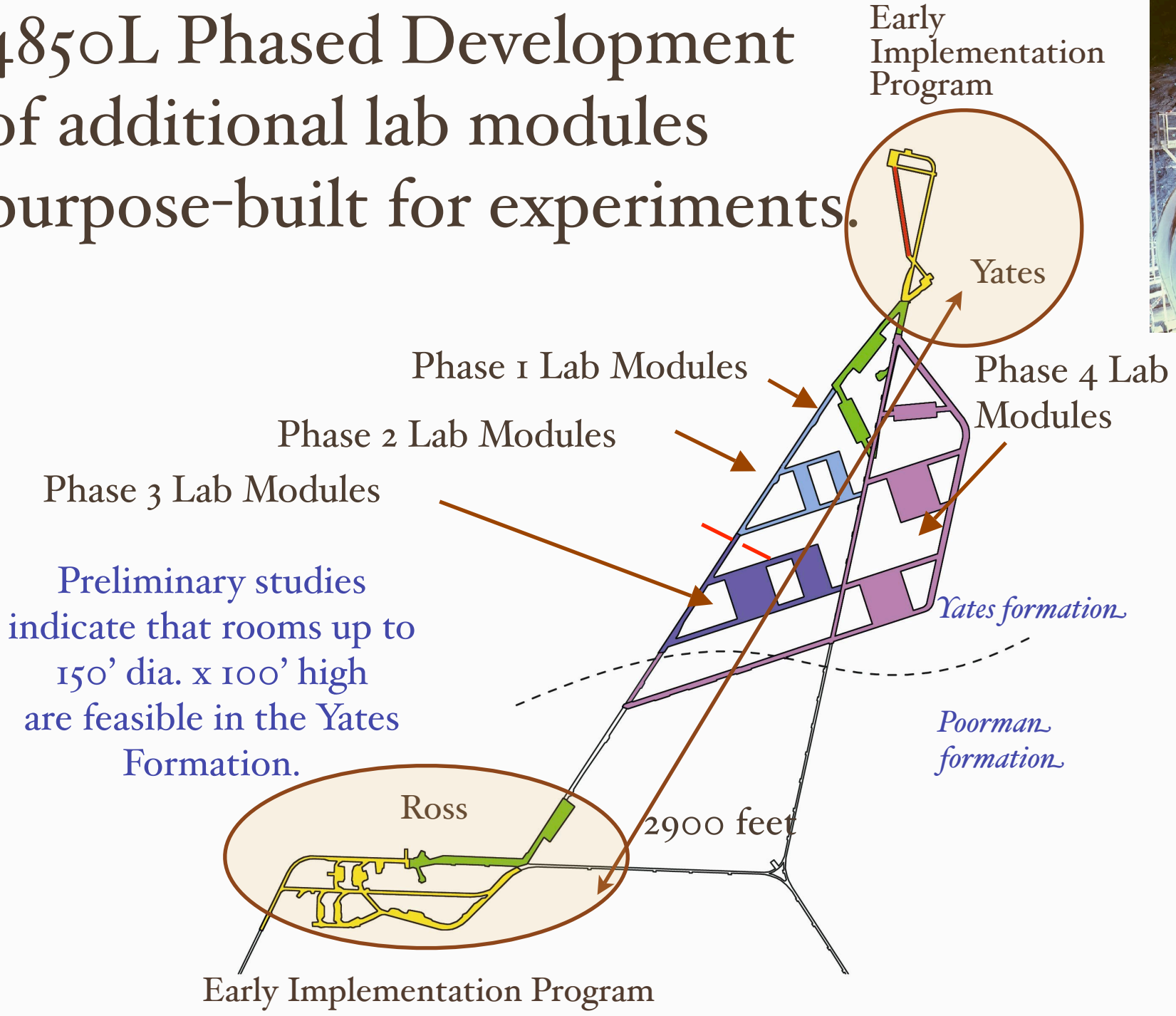
Homestake Mine

Approximate boundary
of transferred property:
186 acres



4850L Phased Development of additional lab modules purpose-built for experiments.

Existing Neutrino Chamber: Davis Experiment 56' x 30' x 26'

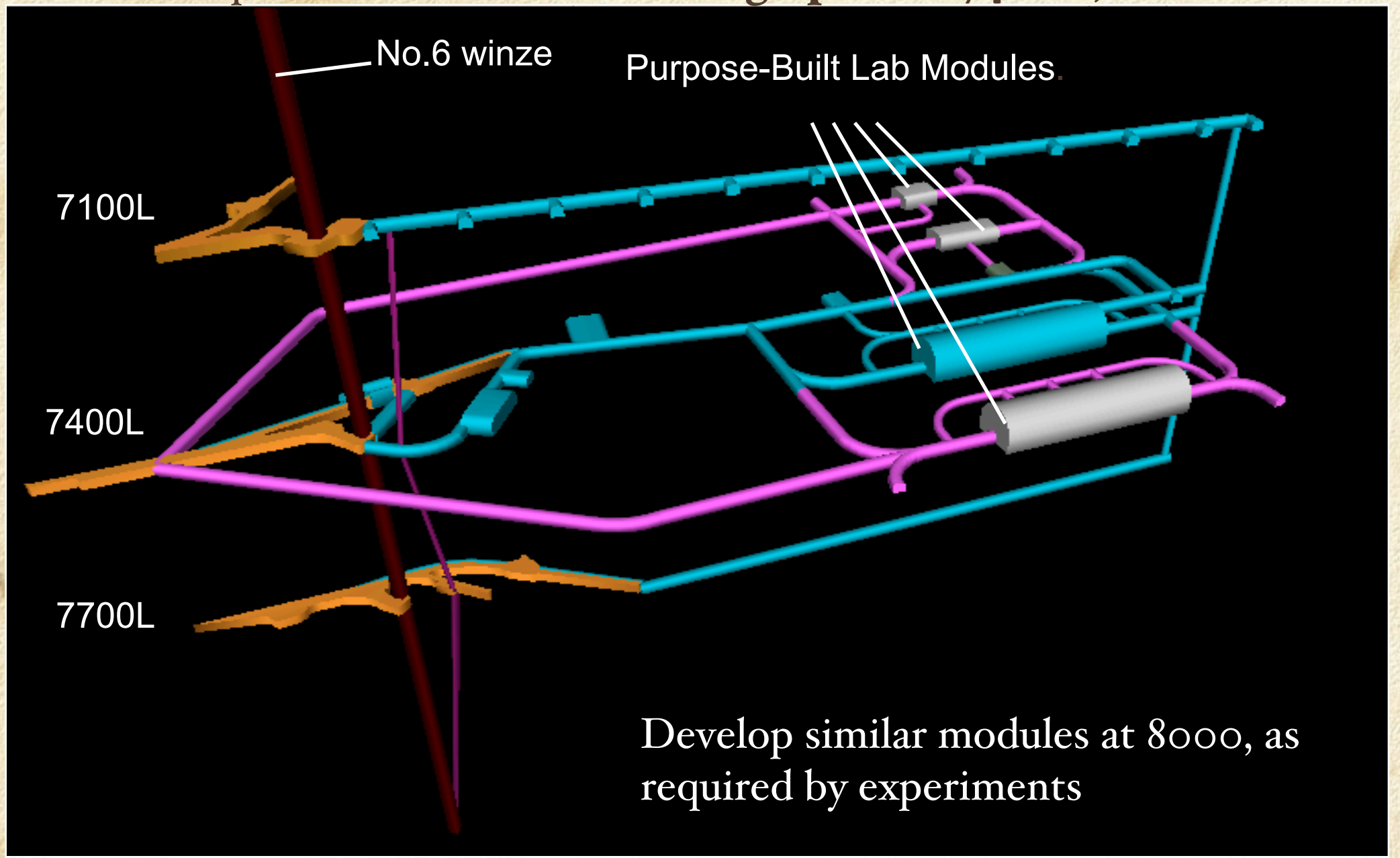


Preliminary studies indicate that rooms up to 150' dia. x 100' high are feasible in the Yates Formation.

7400L & 8000L Campus Phased Development

Earlier Analysis performed in 2004, included in Dynatec Report, including initial Golder study of cavities at depth

Also plan to make use of **Existing Space at 7400L, 8000L**



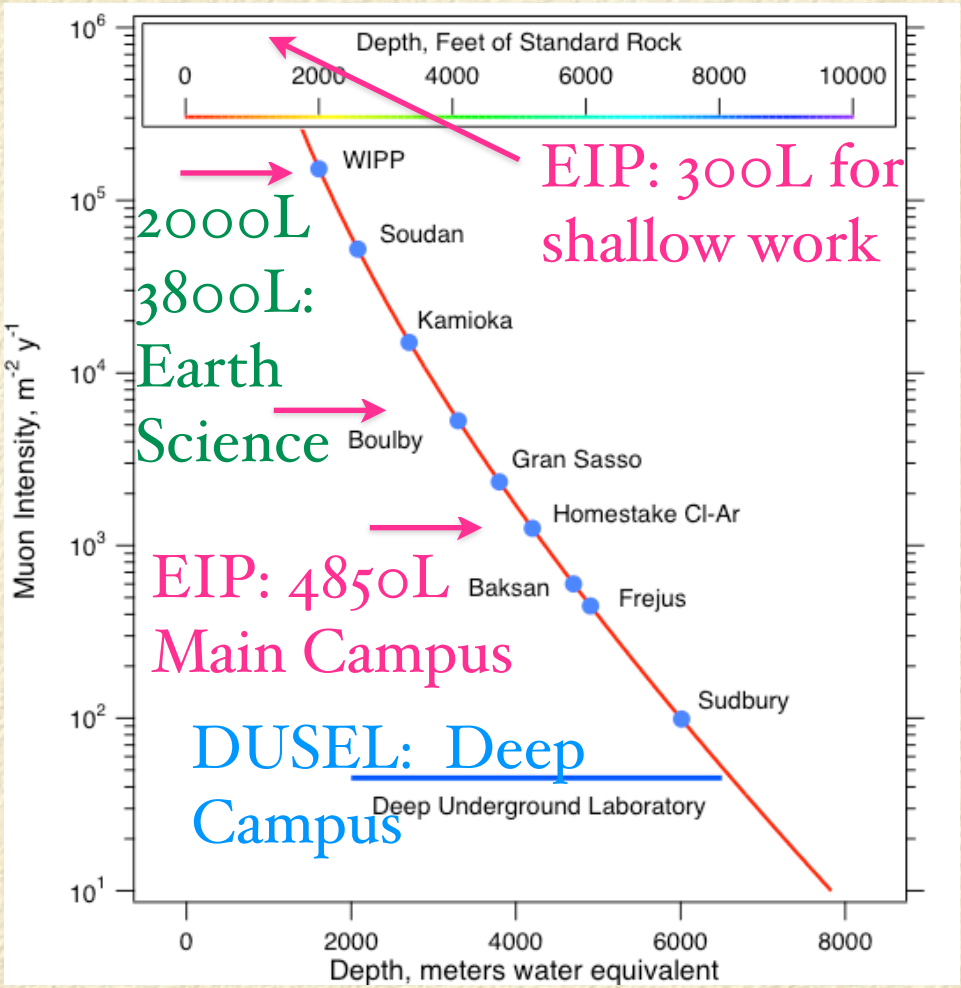
3) Homestake's Early Implementation Program, Initial Suite of Experiments, and Phased Approach to Science

Earth Science & Engineering

Physics

- dark matter
- neutrinoless double beta decay
- geoneutrinos
- long baseline neutrinos
- nucleon decay
- low background counting
- n-nbar oscillations
- nuclear astrophysics
- solar neutrinos
- gravity waves
- …

Education and Outreach



Early Implementation Program

- Taking advantage of State funded laboratory: 2007 - 2012
- **300 L**, **4850 L**, and other levels, e.g. 2000 L, 3800 L
- Ross and Yates Shafts refurbished, safe and operating
- Basic operations, including Safety, Utilities, Services
- Upgrades and enhancements as budget permits
- International Call for Letters of Interest
- Established **Program Advisory Committee in 2005**
  - Charge was to consider the Early Implementation Program, but to be aware of longer term aspects and uses
  - Decision factored in the 5 criteria, National "issues" and Homestake "capacity"

Homestake Program Advisory committee

Physics

Professor Frank Sciulli - Columbia, Co-chair

Professor Ed Kearns - BU

Professor Josh Klein - UT

Dr. Bill Marciano - BNL

Professor Harry Nelson - UCSB

Professor Hank Sobel - UCI

Earth Science and Engineering

Professor Derek Elsworth - Penn State, Co-chair

Professor Sookie Bang - SDSM&T

Mr. Derric Iles - SDGS

Professor Thomas L. Kieft - NM Tech

Dr. Chris Neuzil - USGS

Professor Bill Pariseau -University of Utah

Education and Outreach

Professor Charles Ruch - SDSM&T

Charge to the PAC

1) With the information provided at this initial meeting and with subsequent discussions we request that the **PAC develop of a scientific program well-suited to the Homestake Early Implementation Program (EIP)…**

2) The infrastructure at Homestake may be a limiting factor in hosting all of the proposed expts and uses. The **EIP** will be limited in scope, but we would like to **accommodate as many expt. and educational uses as possible**.

3) We are simultaneously developing the scientific roadmaps beyond the Early Implementation Program. **We are requesting the PAC to consider and advise us on longer term roadmaps for Homestake.** Several of the LOIs offer staged approaches. These may require going deeper in subsequent phases, expanding efforts, etc. The PAC should take into consideration for the EIP the implications of longer term aspects.

Letters of Interest for Homestake

~ 85 LOIs

~ 60% earth science

~ 25% physics

- dark matter
- double beta decay
- geoneutrinos
- long baseline + pdk
- low bckgrd cnting
- n-nbar, cloud phys.
- nucl. astrophysics
- solar neutrinos

~ 5% engineering

~ 5% education

~ other

interest continues to grow

#	Date Received	Title	Discipline
1	11/21/05	Time Dependent Deformation	Rock Mechanics
2	11/21/05	Scale Effects In Rock Mechanics	Rock Mechanics
3	11/21/05	Stress & Rock Properties of the Yates member of the Poorman Formation	Rock Mechanics
4	11/22/05	Mine Engineering & Management Related Activities	Mining
5	11/23/05	DUSEL Education & Conference Center	Education & Outreach
6	12/2/05	Determination of Water Levels & Stress Release during Dewatering	Geology
7	12/2/05	Search for Neutron-Antineutron Transition at Homestake	Physics
8	12/6/05	Plan for Near Future of High Energy Neutrino Physics at Homestake	Physics
9	12/8/05	Hard Rock Underground Mine Mapping & Surveying	Geology
10	12/8/05	Partitioning of CO2, H2O, gold and trace metals between synformal and antiformal fold hinges	Geology
11	12/8/05	Developing an Internet-accessible database of 3D geologic and engineering data	Geology
12	12/8/05	Hydrologic Instrumentation of the Homestake DUSEL	Geology
13	12/9/05	New Paradigms in Sensing	Engineering
14	12/9/05	Effects of Ultralow Radiation Levels on Human Cells	Microbiology
15	12/9/05	Microbial Evolution	Microbiology
16	12/9/05	Workshops	Education & Outreach
17	12/1/05	Effects of Cosmic Rays on the Soft Error Rate of Semiconductor Memory Chips at Ground Level	Engineering
18	12/2/05	Controls on World-Class Homestake Gold Mineralization	Geology
19	12/8/05	Low Radioactivity Measurement Laboratory	Low Backg. Counting
20	12/9/05	Role of Iron Formations in the Making of Giant Gold Deposits	Geology
21	12/9/05	Thermal History of Homestake Mine	Geology
22	12/9/05	Super CDMS	Physics
23	12/9/05	Determination of Diurnal changes in the rotation rate of the earth	Physics
24	12/9/05	Establishing the Physical Footprint for Future Geoscience Research at DUSEL	Geology
25	12/9/05	Developing of a robotic sampler for underground and confined environments	Engineering
26	12/10/05	Homestake Electrical Engineering Laboratory (HEEL)	Physics
27	12/10/05	Homestake Outreach Program (HOP)	Education & Outreach
28	12/10/05	Bioprospecting	Microbiology
29	12/10/05	Analysis of soil-like materials in the mine	Geology
30	12/10/05	Biological effect of low levels of radiation-Health Physics	Microbiology
31	12/10/05	Homestake Neutrinos	Offer to Collaborate
32	12/10/05	Establishing baseline data for microbial populations of the mine before and after dewatering	Microbiology
33	12/12/05	Cloud physics facility and experiments for an underground laboratory	Atmospheric sciences
34	12/11/05	Fracture network characterization at Homestake	Rock Mechanics
35	12/11/05	Risk Assessment of underground space modifications at Homestake	Rock Mechanics
36	12/11/05	Hydrogeology Collaboration on flow path delineation and modification	Earth Sciences
37	12/11/05	Geochemistry collab. for the geochemical evolution of fluids in the Homestake hydrologic system	Earth Sciences
38	12/11/05	Ecology/geomicrobiology collaboration for microbe evolution	Earth Sciences
39	12/11/05	Geophysics collaboration for imaging	Earth Sciences
40	12/11/05	Rock Mechanics and geoengineering collaboration for excavation research	Earth Sciences
41	12/11/05	Couple process collaboration for large block experiments	Earth Sciences
42	12/11/05	Cosmic ray studies	Earth Sciences
43	12/12/05	Characterization and mechanics of faulting and rock fracture at homestake mine	Rock Mechanics
44	12/12/05	Breccia evolution associate with degassing of tertiary veins and dikes at Homestake	Geology
45	12/12/05	Development of a 3D geological model of the Homestake mine area	Geology
46	12/12/05	Detailed geological mapping of the Homestake mine area	Geology
47	12/12/05	Close range remote sensing for mapping of rock in underground excavations	Geology
48	12/12/05	ZEPLIN - a multi ton scale liquid xenon dark matter direct search program	Physics
49	12/12/05	EXO - the enriched xenon observatory for neutrino-less double-beta decay	Physics
50	12/12/05	Educational outreach support infrastructure	Education & Outreach
51	12/12/05	Low-alpha lead and the cosmic-ray equivalency factor	Physics
52	12/12/05	Study of a LANNDD of 100kTon at Homestake DUSEL	Physics
53	12/13/05	Investigation of microbial diversity in subsurface ecosystems	Microbiology
54	12/13/05	Initial low background counting facilities for Homestake	Physics
55	12/14/05	Large block (Pillar) test to study the failure of rock - rock strength and earthquake mechanics	Rock Mechanics

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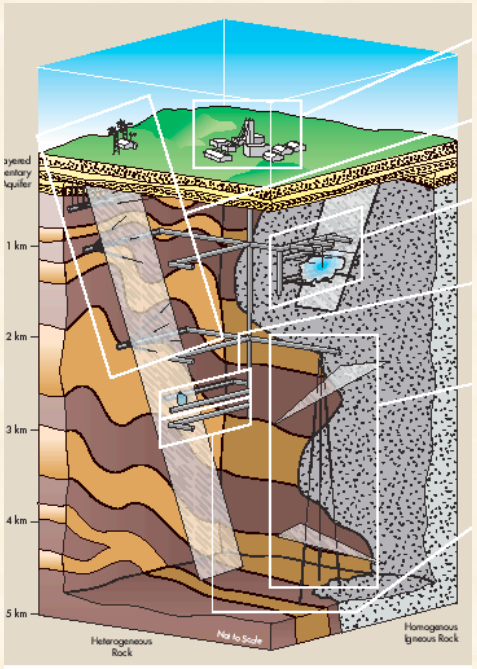
(Earth) Scientific Case for DUSEL at Homestake

Overriding Themes: Dedicated, Long Term Access, Isolation and Scale:

- Science at Time = 0.0



- Multidisciplinary collaborative deep subsurface science
- Complex coupled process (therm-chem-geo-hydro-bio-)
- Limits of Microbial Life at Depth and Deep Biosphere
- Hydrologic Cycling, Deep Energy Flow
- Deep Transport of solids, gas, liquids and organisms
- Multiple cubic km perturbation experiments
- Fundamental Science and Engineering Innovations

- Education, Training, and Public Outreach
- Expanding regional scientific infrastructure, training and opportunities

Implement geomicrobiology collaborations (significantly grounded with regional institutions) at reentry, shallow, 4850, and the 8000 deep lab with a phased approach: baseline microbial data before & after dewatering, bioprospecting, and examination of life at depths

1) Early research focuses on the adaptation and transport of surface microbial communities to deep environments. *The extensive excavations over 125 years offer the unique opportunity to evaluate evolution/adaptation, from old near-surface mine workings to recent drifts at depths.*

2) Long term focus is on the characterization of ancient and present day, thermophilic, subsurface microbial communities. *A multi-institutional, multidisciplinary research team will acquire and process samples from borehole coring and from drift advancement into virgin rock formations, and from old stopes and drifts.*

2006-2007: Characterization sample collection along the drifts and available ground waters during inspections

2008-2009: Initiate 4850 experiments, upper test block instrumentation, characterization, coreholes and groundwater testing; dewatering studies

2010-2015 Lower block instrumentation, characterization, ecology and geomicrobiology testing

2013-? Limits of Life from deep lab boreholes, coupled process testing at selected blocks, comparative -omics

from T. Phelps

Geomicrobiology (>15 LOI's to date)

- **Early Reentry LOI's**
  - Bioprospecting (LOI 28)
  - Robotic sampling (LOI 25)
  - Mine soil weathering (LOI 29)
  - Microbial ecology + geomicrobiology (LOI 38, 53a)
  - Corrosion of mining structure (TCO3+LOI38, 53a)
- **4850 Level LOI's**
  - Microbial ecology + geomicrobiology (LOI 3, 53a, 83)
  - Deep Biogeochemical Cycles (LOI 70, 38, 83)
  - Transition biogeochemistry and impact on geology (LOI 75, 79)
  - Intermediate Coupled Processes Laboratory (LOI 38, 53a, 76)
    - Bioprospecting (LOI 28)
    - Robotic sampling (LOI 25)
    - Mine soil weathering (LOI 29)
    - Corrosion of mining structure (LOI 38, 53a, 77)
- **DUSEL – deep level – LOI's**
  - Limits of life (3+ km borehole array) from 8,000 level (LOI 38, 15, 80, 81)
  - Deep Coupled Processes Laboratory (LOI78, 83)
  - Deep Biogeochemical Cycles (LOI 70&38)*
    - Bioprospecting (LOI 28)
    - Robotic sampling (LOI 25)
    - Mine soil weathering and corrosion (LOI 29, 38, 53, 77)

Summary

- Hundreds of subsurface biogeoscientists are poised for DUSEL at Homestake with projects ‘grounded’ in regional institutions
- DUSEL at Homestake represents an exciting opportunity for collaborative interdisciplinary examination of: deep biosphere, evolution and genomics, hydrologic and fluid cycling, deep flux of energy, water/rock interactions, and geophysics, with regionally focused enhanced education and outreach
- Homestake is unique: HERE, SCIENCE at T=0.0, dedicated, controlled access, isolated environment, multiple scales, many disciplines, E&O
- Biogeoscientists have prepared for two decades ground truthing hypotheses and procedures for this grand opportunity

We look forward to collaborations

from T. Phelps

1. Reactive Chemical Transport
2. Subsurface Biochemical Processes
3. Heat Flow

Geochemical Hydrodynamic Scientific Focus

- **Mineral - Fluid Reaction Kinetics**

  How are reaction rates influenced by factors such as temperature, changes in lithology, freshly fractured surfaces?

- **Fracture - Matrix Interaction**

  What are the key factors affecting chemical exchange between matrix pore fluids and fractures?

- **Biomineralization**

  To what extent and under what conditions can biological communities impact the dissolution and precipitation of minerals in the rock?

- **Microbial Activity**

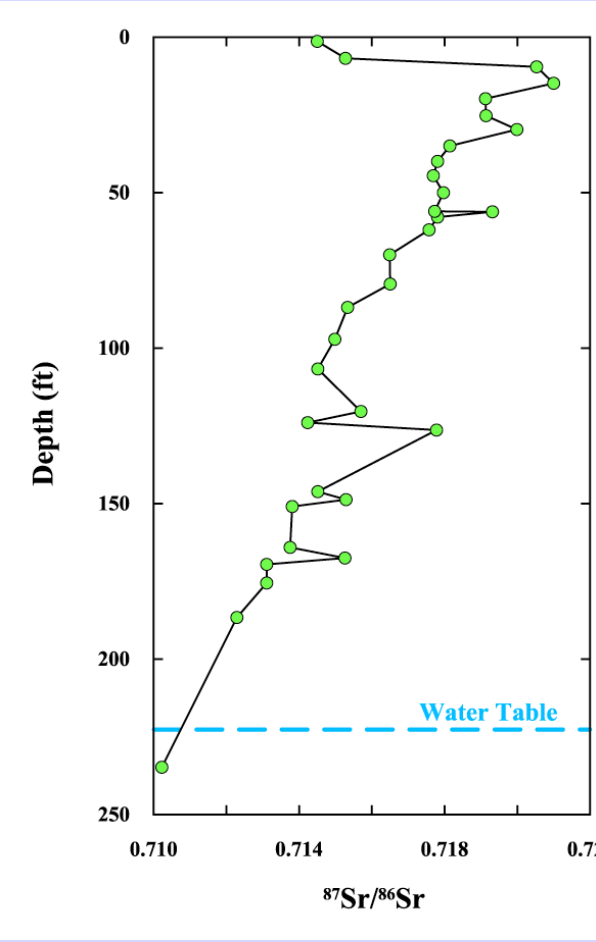
  How do microorganisms effect the chemical environment in the subsurface? (CH_4, CO_2, ..)

- **Distribution of Radionuclides in the Crust**

  What fraction of crustal heat flow is derived from radioactive decay?

- **Fluid Transport of Radionuclides**

  Can aqueous transport of radionuclides significantly affect heat flow in the crust?



LOIs Summary, Joe Wang, LBNL
March 20, 2006, Lead, SD

Rock Mechanics LOI's

Time Dependent Deformation; Scale Effects in Rock Mechanics; Stress & Rock Properties in the Yates member of the Poorman Fm.	Bill Pariseau U. Utah
Determination of Water Levels & Stress Release during Dewatering	Larry Stetler SDSMT
Fracture network characterization at Homestake; Risk Assessment of Underground Space Modifications at Homestake	Matthew Mauldon Virginia Tech
Rock Mechanics and geoengineering collaboration for excavation research; Couple process collaboration for large block experiments	Joe Wang LBL
Characterization and mechanics of faulting and rock fracture at Homestake Mine	Steve Martel U. Hawaii
Large block (pillar) test to study the failure of rock – rock strength and earthquake mechanics	Derek Elsworth Penn State
Coupled Mechanical-Hydrological Behavior of Fractured, Rock Mass	Herb Wang U. Wisconsin
Long term seismic and seismologic monitoring of stress and fluid dynamics in the upper crust	Serge Shapiro Freie Universitat Berlin

from H. Wang

Rock Mechanics Research Themes

- Rock mechanics program can inform physics lab construction, and conversely benefit from long-term monitoring of deformations resulting from excavations
- Deformation of fractures influences fluid flow and transport, and vice versa; hence coupling with microbial life processes
- Rock failure
- Scale effects of stress and deformation

Rock Mechanics Research Plan

1. **Characterize** fractures, fluid flow, and stress field at different spatial and temporal scales directly and with geophysics

2. **Monitor** fracture, stress, deformation, and hydrologic changes directly and with geophysics as mine is dewatered and physics rooms are excavated. **Induce** stress changes using heat.

3. **Model** coupled stress, deformation, fluid flow

from H. Wang

3 1) Physics Programs at Homestake

- National Academy **Quarks to Cosmos**
  1. What is the Dark Matter?
  2. What are the masses of the Neutrinos, ...?
  5. Are Protons unstable?
  7. Did Einstein have the last word on Gravity?
  11. How were the ... elements made?

- 2001 Bahcall report
- The 2002 Nuclear Physics Long Range Plan
- The NeSS workshop, "Neutrinos and Beyond"
- The Neutrino Facilities Report
- The Quantum Universe: The Revolution in the 21st Century Particle Physics
- The Earthlab report
- 2004 Neutrino Matrix APS report
- National Science and Technology Council Committee on Science
- The Physics of the Universe
- Facilities for Future of Science

- Dark Matter
- Neutrinoless Double Beta Decay
  - ν mass
  - mass hierarchy
  - Dirac vs Majorana
- Solar Neutrinos
  - tests of oscillations, solar physics
  - sterile ν
  - MNSP matrix (12 and 13)
- Geoneutrinos
  - supernovae ν
  - p-e-p solar ν
- Long Baseline Neutrinos (Requires ν beam)
  - CP violation
  - Mass hierarchy
  - MNSP Matrix elements (13)
  - atmospheric ν, MNSP Matrix (23)
- Nucleon Decay
- Nuclear Astrophysics
- Others
  - n-nbar (requires vertical shaft)
  - cloud physics (requires vertical shaft)
  - gravity wave experiments (requires long drift)

Comparative General Characteristics: DM + $o\nu\beta\beta$

L.O.I.	GOALS	DETECTOR	SIZE	CRYO/GAS ?	STAGE
MAJORANA	DBD	Ge crystals	Sml ~ Med	LN_2	AdvR&D/CD0
EXO	DBD	LXe	Med ~ Lrg	LN_2 /LXe	AdvR&D & Expt/CD0 (WIPP)
XENON	DM	LXe	Med ~ Lrg	LN_2/LXe	AdvR&D & Expt(LNGS)
ZEPLIN	DM	LXe	Med ~ Lrg	LN_2/LXe	AdvR&D & Expt (Boulby)
Super-CDMS	DM	Ge & Si crystals	Med ~ Lrg	Dilution fridge (He)	AdvR&D & Expt (Soudan)
miniCLEAN	DM/solar nu	LAr & LNe	Sml ~ Xlrg	LAr/LNe/LN_2	R&D
DRIFT	DM	CS_2	Med ~ Xlrg	CS_2	R&D (Boulby)
TPC	DM/DBD/solar nu	Various gases	Med ~ Xlrg	HiPress/He CH_4 , CS_2	R&D
SIGN	DM/solar nu	Ne	Sml ~ Xlrg	Hi Press Ne	R&D

Some illustrative examples from workshop: people, hardware, need,-----etc.

from B. Lanou

Homestake Dark Matter and Neutrinoless Double Beta Decay LOIs: Candidates for:

		DUSEL	
L.O.I. (rec'd)	E.I.P.	Initial Suite	Deep/or Long-term
MAJORANA $0\nu\beta\beta$	R&D Expt.(yes)	yes	yes
EXO $0\nu\beta\beta$	EXO200 (R&D and Expt @ WIPP)	yes	yes
XENON DM	yes	yes	yes
ZEPLIN DM	(now @ Boulby)	?	yes
Super-CDMS DM	(now @ Soudan)	SNOLab	SNOLab
miniCLEAN DM	R&D (yes)	yes	yes (+ solar ν)
DRIFT DM	(now @ Boulby)	R&D?	yes
TPC DM	R&D (yes)	R&D Expt - 4850?	yes - 4850?
SIGN DM	R&D (yes)	yes	yes

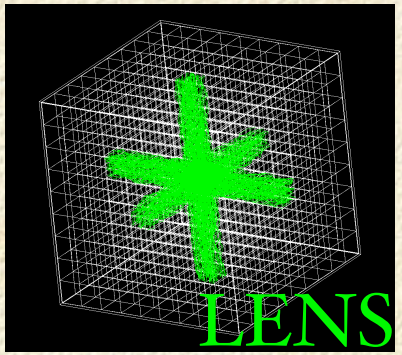
from B. Lanou

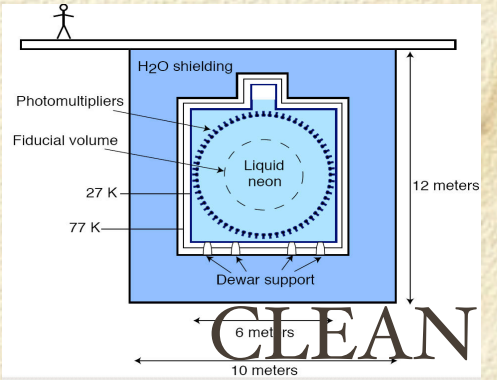
Dark Matter and Neutrinoless Double Beta Decay

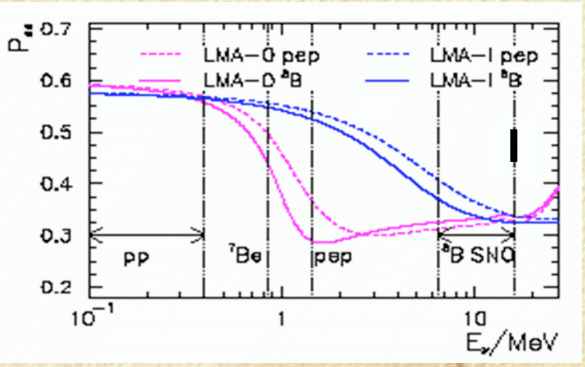
- Vigorous Program in Dark Matter and Neutrinoless Double Beta Decay Experiments - $0\nu\beta\beta$ at CD0
- Homestake programs would include essential support infrastructure - chemical facilities, low background counting, storage, assembly - at a variety of levels, including drive in.
- DM experiments in various stages of R&D and readiness for deployment, several in advanced stages - good match to R&D and EIP phases
- Neutrinos - 2 of the 3 (all of the US-lead) $0\nu\beta\beta$ experiments applied to Homestake, one for EIP, one for DUSEL
- Program would naturally evolve from 4850 then 7400 then larger and/or deeper.

Measuring the solar pp-ν flux directly lets us:

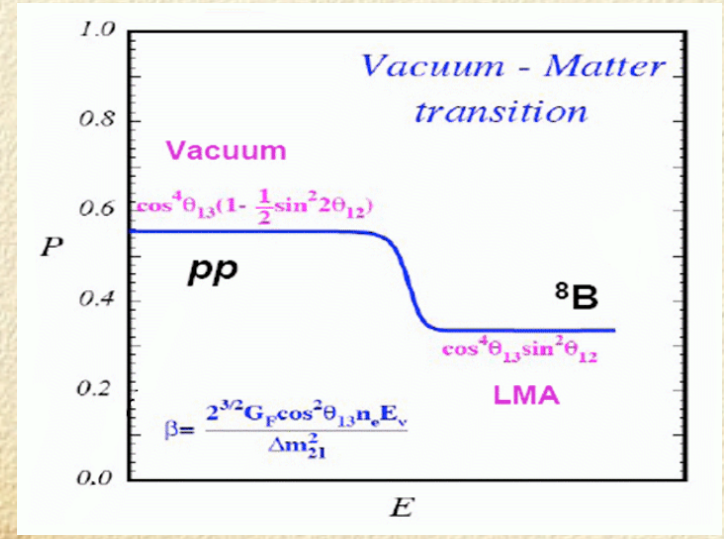
- Test solar ν-luminosity to ~ *1%*
- Test for sterile neutrinos
- Test CPT (with KamLAND $\overline{\nu}_e$-result?)
- Confirm MSW (vacuum vs. matter oscillations)
- Measure θ_{13} (or with θ_{13} from reactors *confirm Chooz)*
- What if LSND is right?
- Any forced re-interpretation of solar result would have major impact on all ν programs
- Guard against complacency
- Good Fit to Homestake: R&D then ISE

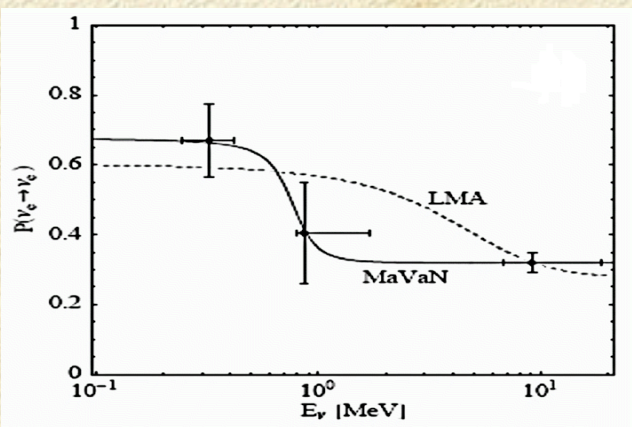






Non-standard interactions





Mass-varying neutrinos

from B. Vogelaar

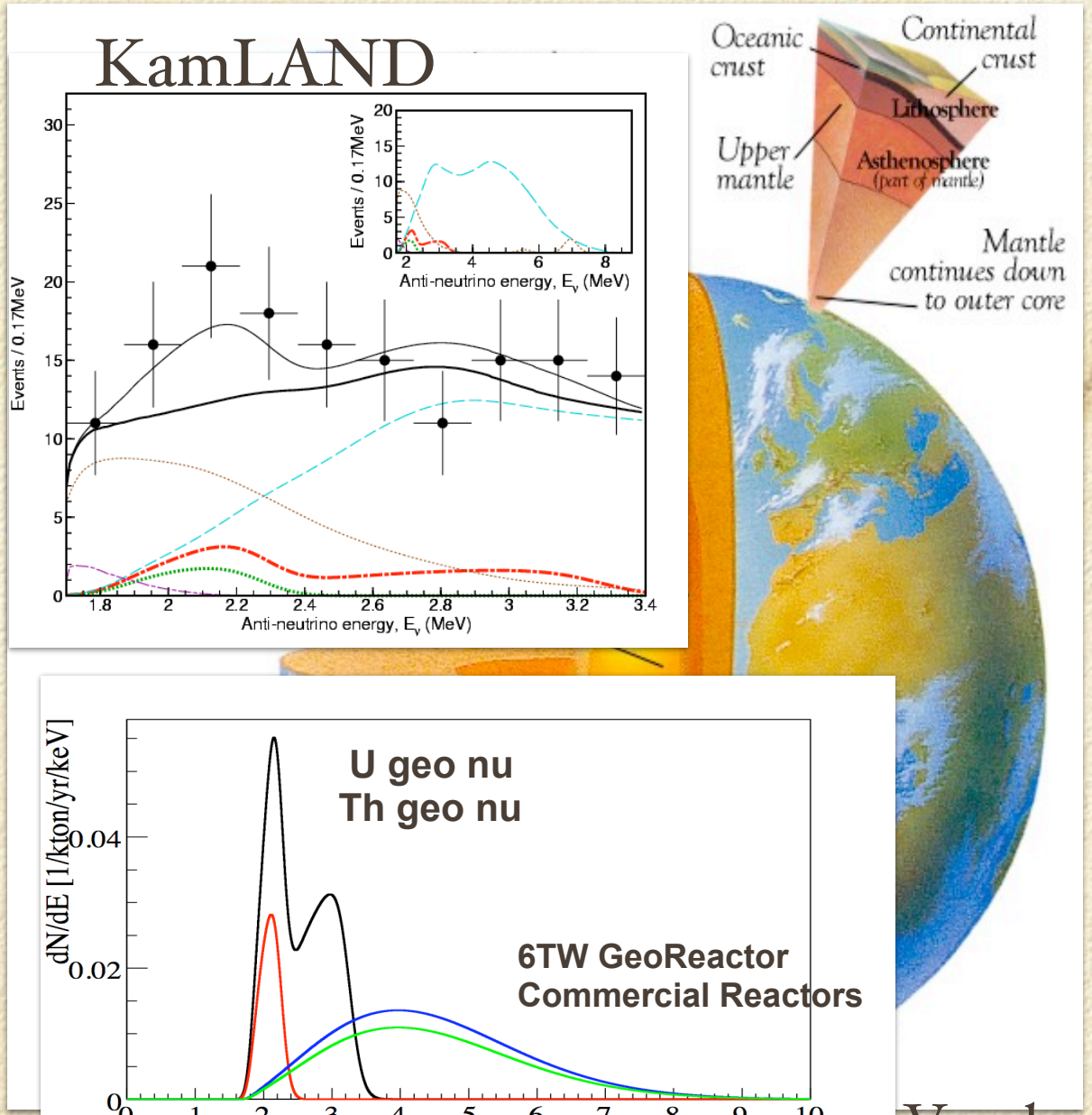
Geoneutrinos - New Neutrino Frontier

Status similar to that after Davis Experiment on solar νs

- Evolution of Earth's Heat
  Sources: Total ~ 40 TW
  Radiogenic Part?
  Georeactor at core?
- Measure νs from U, Th, K
- Resolve Models of Earth
  plate / crust - largest ν flux
  Latest: geoneutrinos exist
- LOI #71

Excellent match to Homestake

- Continental location - model well defined
- Reactor backgrounds - one of lowest
- Midlevel depth OK - Space for large detectors
- R&D in the near future
- Good fit to ISE
- Good ability to detect Supernovae νs, p-e-p solar νs



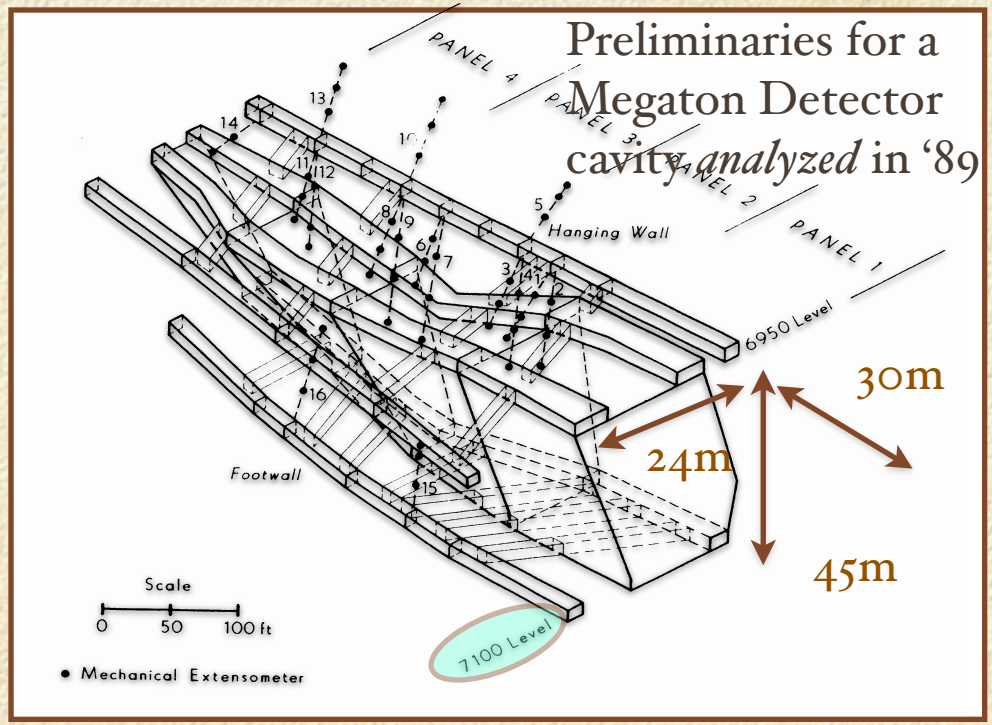
Vogelaar

Long Baseline Neutrinos at Homestake

- Letters of Interest Received from:
  - Water Čerenkov Detectors ~ 100 kt (#08 + UNO) 100kT to 1MT
  - Liquid Argon TPCs (#52 and *Fleming*) ~ 25kT
  - Large Cavity Engineering and Rock Mechanics (#03)
  - Homestake Extant Information (Core Archive) (#11)
- Place in context of FNAL/BNL Working Group, APS *Neutrino Matrix*, *NuSAG report* and Long Range Planning (NP) discussion
- A program addressing engineering issues, mining issues, even resolving siting issues would be appropriate and easily initiated on the EIP time-scale. The basic siting, cavity structure, baseline costs and schedule would be developed. Begin the work of planning for massive excavations and make significant progress in designing this facility in EIP
- Homestake would strive to ensure that cavities would not be the critical path for Long Baseline Neutrinos and Nucleon Decay programs

Existing Studies on Large Room Stability, Evaluations at Homestake, Existence Proofs

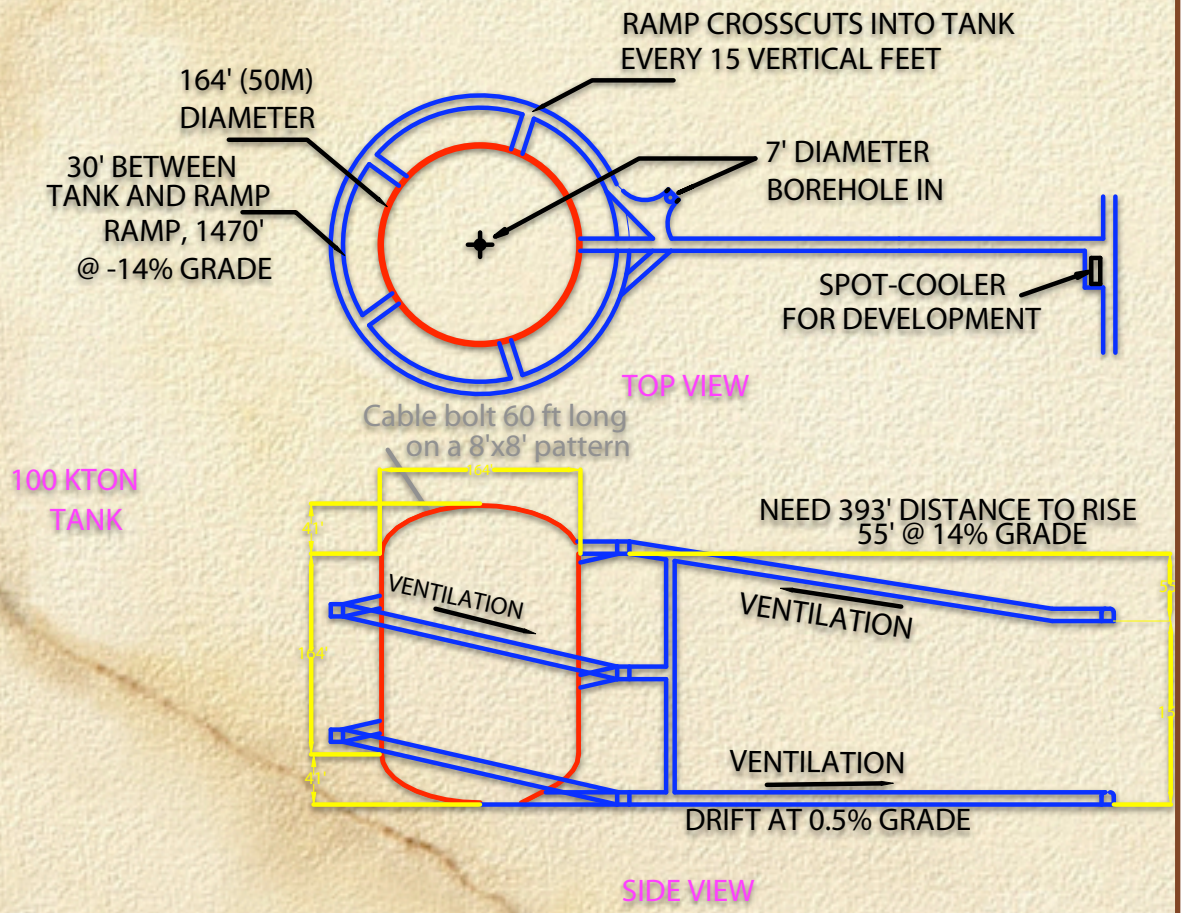
- Vertical Crater Retreat (45-61 m high) evaluations, Pariseau *et al.*, BOM, 1985
- 61 m dia. x 122 m cylinders, stable at 4850 and 6800, Johnson and Tesarik, NIOSH, 2000
- Linear arrays of 50 m dia. x 50 m cylinders with 100 m spacing are stable at 4850', Callahan *et al.*, RESPECT, 2001

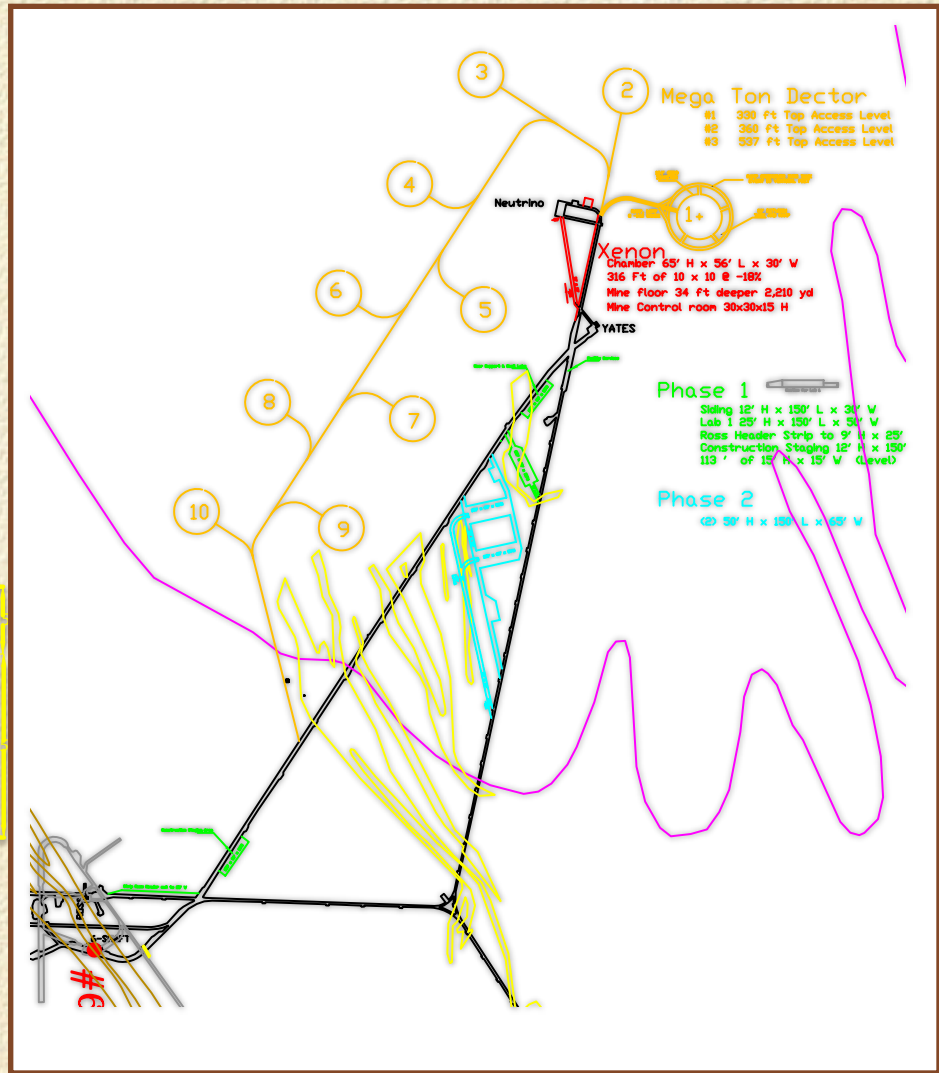


Pariseau, W.G. and F. Duan (1989) "Finite Element Analyses of the Homestake Mine Study Stope: An Update". Proc. 3rd Intl. Symp. on Numerical Models in Geomechanics. (NUMOG III). Elsevier Applied Science, London and New York, pp 566-576.

Megaton Modular Multi-Purpose 100kT Neutrino Detector

Construction Methodology





Mark A. Laurenti

Why Very Long Baseline?

observe multiple nodes in oscillation pattern

☞ less dependent on flux normalization

neutrino travels larger distance through earth

larger matter effects

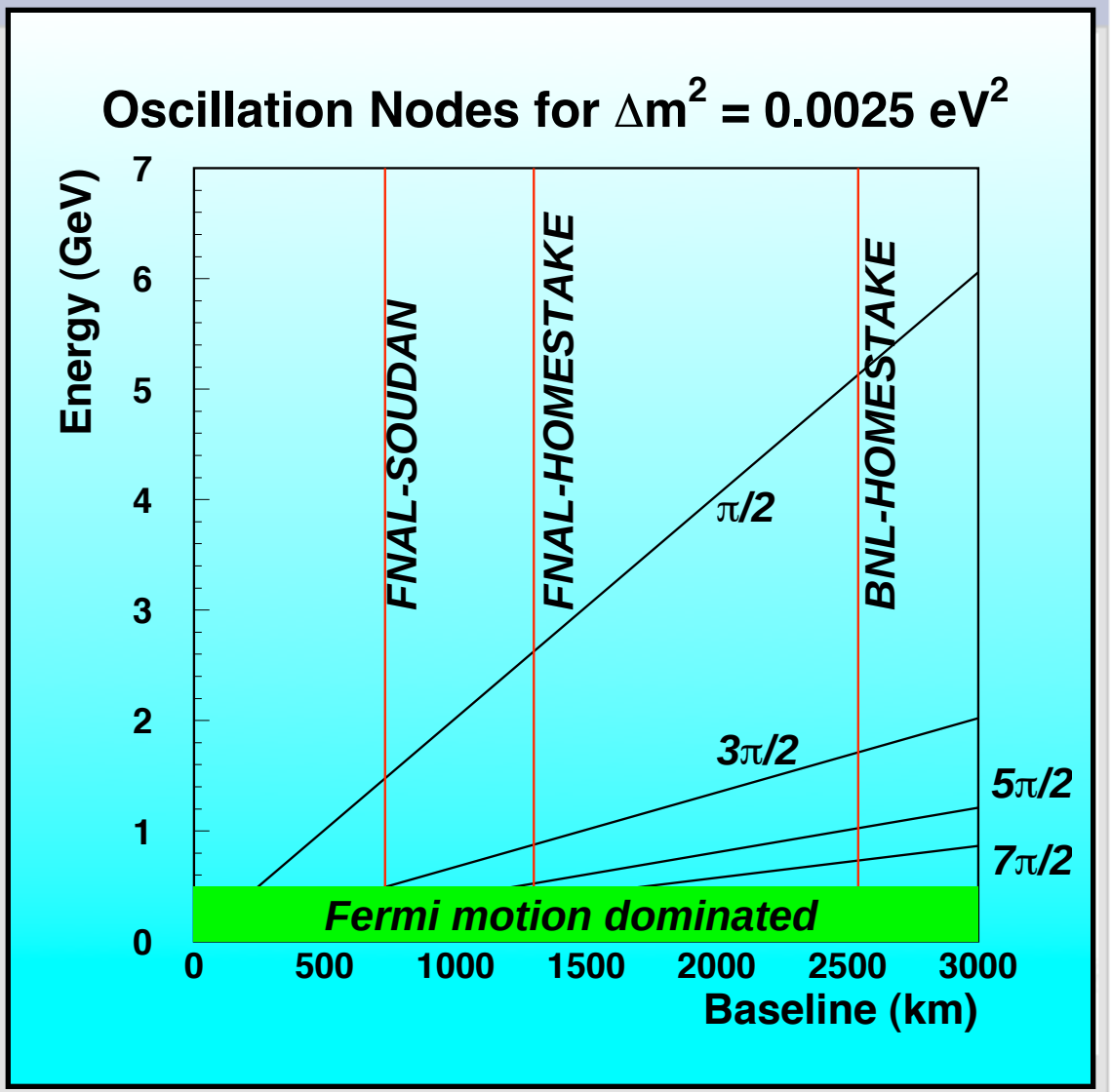
flux ~ L^{-2}: lower statistics

but: CP asymmetry ~ L

sensitivity to δ_{CP} independent of distance!

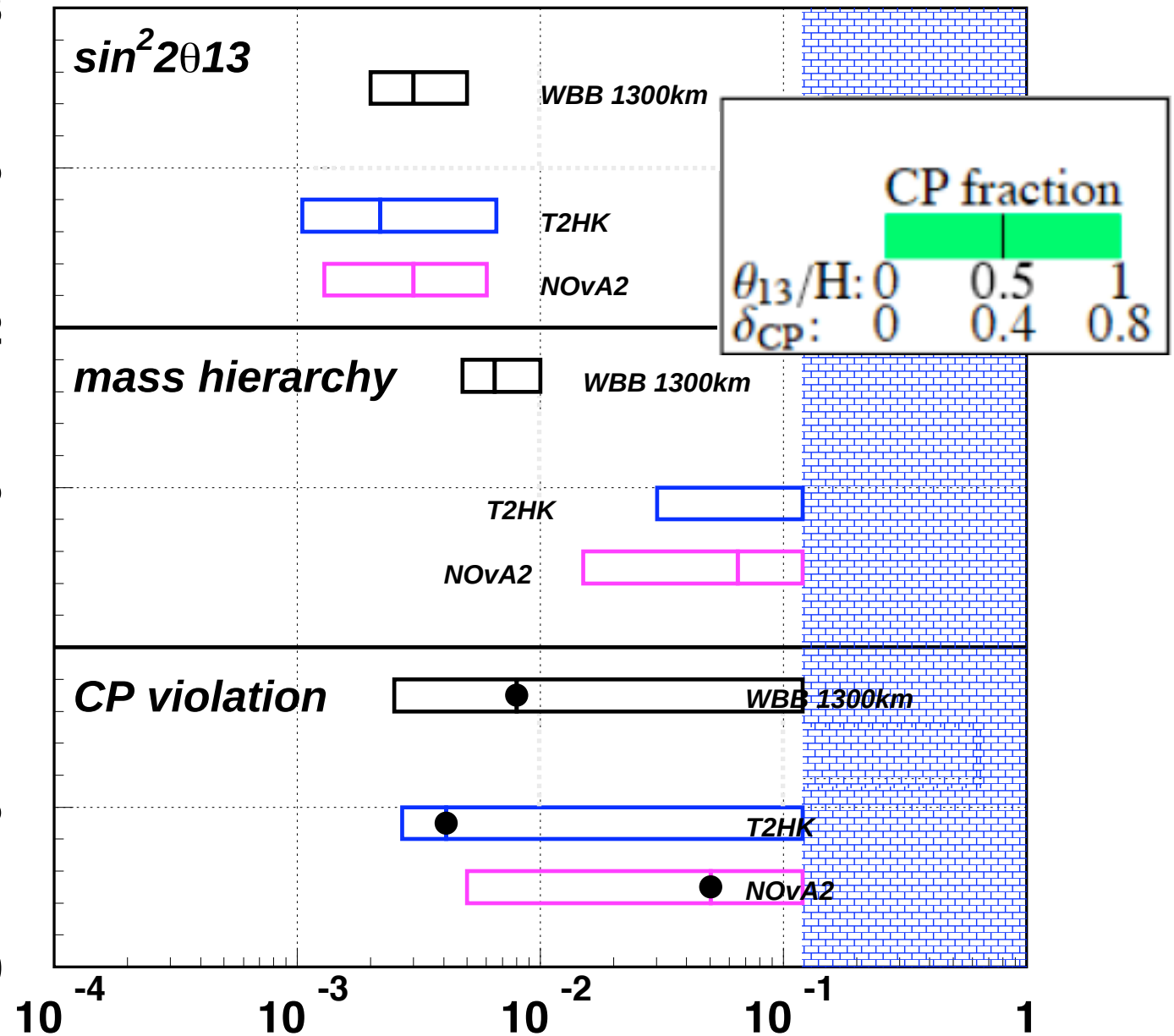
better S:B

(Marciano hep-ph/0108181)



Comparison of 3σ reach

adapted from M. Diwan



Assumptions

- WBB:
  nu:100kT*2MW*6yr.
  antinu: 100kT*2MW*6yr
  syst: 10% on bck
  Antinu runnining is over-constraint for normal hierarchy.
- T2HK:
  nu: 1000 kT*4MW*3yr
  antinu: 1000kT*4MW*3yr
  syst: 2% on bck
- NOVA2:
  nu:30kT*2MW*6yr+
  80kT*2MW*3yr
  antinu: same*6yr+3yr
  syst: 5% on bck

Office of Science
U.S. DEPARTMENT OF ENERGY

	ReEntry	Early Implementation Program			DUSEL Initial Suite of Experiments			Deep Homestake/Expanded 4850L		
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Long Baseline Neutrinos + PDK										
Water Cerenkov		Cavity Geotechnical Studies, Design			Cavity Construction 100kT Module			Long Baseline Nu Program		
LAr/HSD		300L	300L	300L	Cavity Construction 100kT Module			Long Baseline Nu Program		

See Chang Kee's talk

Astrophysical Neutrinos, PDK

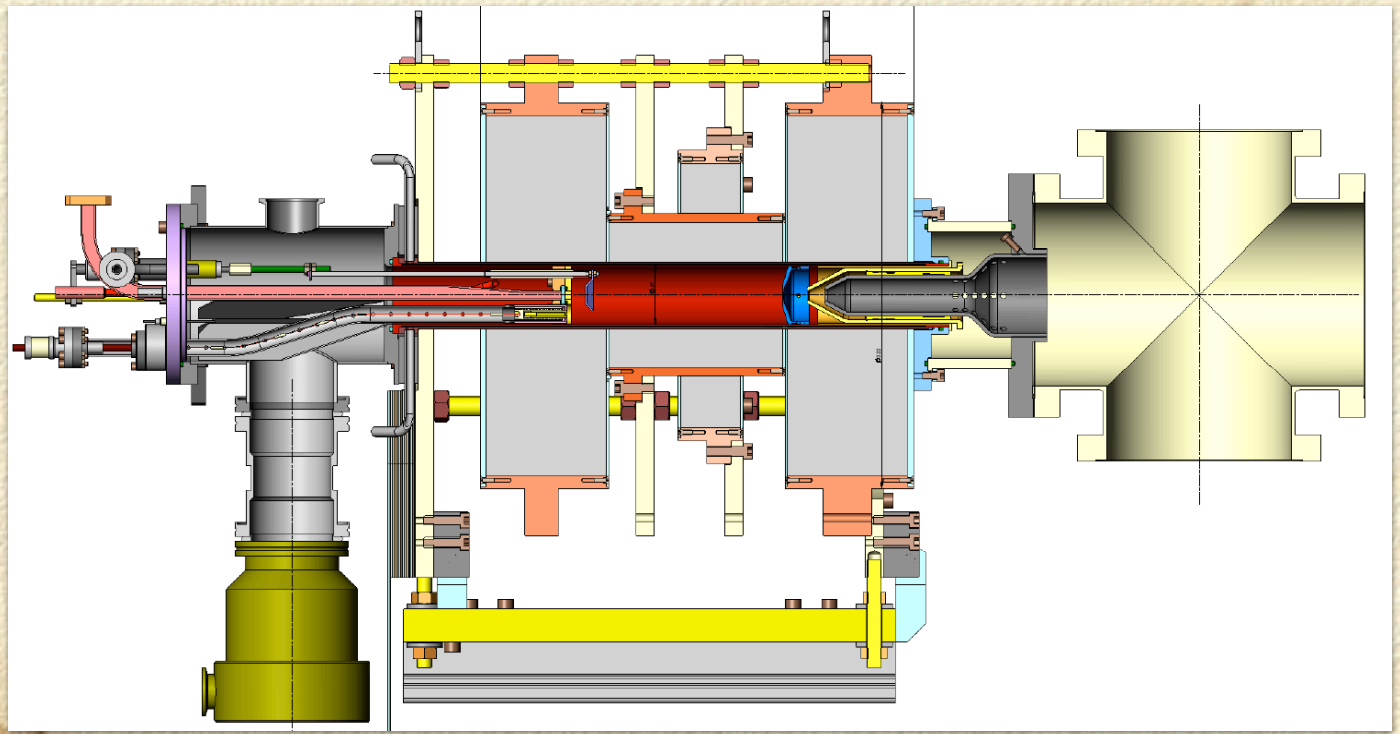
Event rates. LMD-1(100kT), assume 5 yrs

- Atmospheric Nus: ~10000 muon, ~5000 electrons. (Ref: Kajita nnn05)
- Solar Nus: >63000 elastic scattering E>5MeV (including Osc.) (Ref: uno)
- Galactic Supernova: ~30000/10 sec in all channels. (~1000 elastic events). (Ref: uno)
- Relic Supernova: (ref: Ando nnn05)
  - flux: ~5 (1.1) /cm^2/sec E_ν>10 (19) MeV
  - rate: 75 (35) events over backg ~100 !
- Proton decay LMD-1x10yrs ⇒ 3x10^{34} yrs ($p \rightarrow e\,\pi^0$)

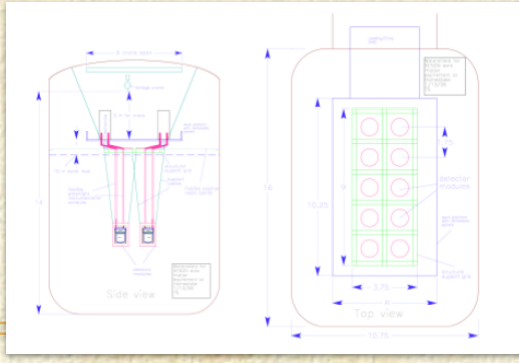
Nuclear Astrophysics

- High Current Accelerator (LDRD project at LBNL) (LOI 64)
- LUNA (Gran Sasso) looking for space in coming year or two to expand and adapt their facility, working with US physicists on joint programs.
- Nuclear astrophysics could move in rapidly at Homestake, current plans and R&D suggest 2008 or 2009 - fits ISE

Nucleosynthesis:
Origins of the light elements
pp chain
CNO reactions
Refinements for solar models
Precision Astrophysics



Highlights for Early Common Infrastructure



- Low Background Counting, Material Assay, Ultra-low Background Materials (LOI # 54, MRI, NNSA application)
- Ultra-low background Material Fabrication Facilities - Copper growing Facility
- Critical to DM and $0\nu\beta\beta$
- Potential NNSA and DHS funding paths
- 300L with drive-in access well suited for these applications
- A growing interest in the 300L, by a variety of users: easy access, separates *Chemical* processes from experiments, strong R&D options and potentials

Homestake's Science Program

	ReEntry	Early Implementation Program			DUSEL Initial Suite of Experiments			Deep Homestake/Expanded 4850L		
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Common Infrastructure										
Ultralow background Materials		300L			300L					
"Water Room"			4850L		4850L					
Low Background Counting		300L	4850 L		300L + 4850L					
Education and Outreach	Surface	300L		4850L	Surface, 300L, 4850L, deep modules					
Physics										
Dark Matter										
XENON		300L	4850L Water Lab		Continued 4850 Development			Continued or Deep Labs		
ZEPLIN		Boulby?						Deep Homestake		
miniCLEAN		300L	R&D	R&D	4850 Deployment			Deep Homestake (plus solar neutrinos)		
DRIFT		Boulby?			R&D at Homestake?			Possible interest		
TPC		300L	R&D	R&D	R&D then Experiment 4850			Continued or Deep Labs		
SIGN		300L	R&D	R&D	4850 Deployment			Continued or Deep Labs		
superCDMS	Soudan	Soudan	Soudan?	SNOLab	SNOLab	SNOLab	SNOLab			
Neutrinoless Double Beta Decay										
Majorana		300L	R&D	Lab Outfitting	Run 1st Module			Deep Homestake with add'l Modules		
EXO			R&D WIPP EXO200		EXO 4850			Continued or Deep Labs		
Astrophysics					Nuclear Astrophysics Program at 4850L					
Geoneutrinos			R&D		4850L Deployment of Geoneutrinos					
Long Baseline Neutrinos + PDK										
Water Cerenkov		Cavity Geotechnical Studies, Design			Cavity Construction 100kT Module			Long Baseline Nu Program		
LAr/HSD		300L	300L	300L	Cavity Construction 100kT Module			Long Baseline Nu Program		
Solar Neutrinos (LENS)		300L	R&D	R&D	4850 Deployment			Continued or Deep Homestake		
Subsurface Geoscience										
Geology and Rock Mechanics	Inspect	Surveys, Monitoring, Inspections			4850 and above ISE			Continued and Deep Homestake		
Hydrology	Inspect	Surveys, Monitoring, Inspections			4850 and above ISE			Continued and Deep Homestake		
Coupled Processes	Inspect	Surveys, Monitoring, Inspections			4850 and above ISE			Continued and Deep Homestake		
Extant Information and DB	Core	Surveys, Monitoring, Inspections			4850 and above ISE			Continued and Deep Homestake		
Subsurface Engineering										
Geotechnical Studies	Inspect	Geotechnical Studies, Coring			4850 and above ISE			Continued and Deep Homestake		
General Underground Construction	Inspect	Geotechnical Studies, Coring			4850 and above ISE			Continued and Deep Homestake		
Geomicrobiology										
Search for Life & Limits of Life	Inspect	4850 Drill Station			4850 and above ISE			Continued and Deep Homestake		
Bioprospecting	Inspect	Surveys, Monitoring, Inspections			4850 and above ISE			Continued and Deep Homestake		
Ecology	Inspect	Surveys, Monitoring, Inspections			4850 and above ISE			Continued and Deep Homestake		
Environmental Studies	Inspect	Surveys, Monitoring, Inspections			4850 and above ISE			Continued and Deep Homestake		

Perishable Information

Rock Mechanics/Hydrology/Coupled Processes/Engineering Large Scale Experiments

Geomicrobiology/ecology/biology/geochemistry Modules and Field Work, in situ work

4) Summary: Homestake EIP & DUSEL

- Diverse program, strong synergistic links from T=0, very broad Physics program, excellent Education opportunities:
  - Dark Matter, Neutrinoless Double Beta Decay, Solar Neutrinos, Geoneutrinos, Long Baseline Line, PDK, Nuclear Astrophysics, (Gravity waves), ...
- Owner, Insurance, Liability Issues dealt with by SDSTA.
  - South Dakota sponsored 4850 Lab: EIP 2007 - 2012
- Early Science Program being prepared for 2006/7
  - 300L (horizontal access)
  - 4850L (+ higher levels)
- Phasing into Initial Suite of Experiments 2008/9 then Deep Experiments down to 8000 and extended use of other levels
- Excellent match to many problems of the highest importance to Physics, Earth Science, Engineering, Education

Homestake EIP & DUSEL

- Dedicated facility - no interferences or limitations from host mining entity to the parasitic scientific users, the future is determined by scientific needs and requirements not commodity prices
- Multidisciplinary - from the start a culture strong sharing of knowledge, resources, operations, including Homeland Security, industrial and engineering uses and R&D
- Management, Organization and Safety - aligned with science not the extraction of ore
- Expandable and Adaptable - there are large drivers for decades of underground research, need a site to match this need, there is already demand beyond current lab capacity and demand is growing
- Evolutionary - as science demands DUSEL must adapt to the requirements - depth, size, access, infrastructure, techniques
- DUSEL is Aligned with Nuclear Physics, Earth Science, National Academy, APS and Priorities: working within Agencies' DUSEL Process

Homestake PIs, Senior Personnel & Coordinators

- Yuen-dat Chan, LBNL (Other uses)
- Milind Diwan, BNL (lbl, pdk)
- Reyco Henning, LBNL (ονdbd, dm)
- Ken Lande, Penn (lbl, pdk, geo-neutrinos)
- Bob Lanou, Brown (neutrinos, solar neutrinos)
- Chris Laughton, FNAL (engineering)
- Kevin T. Lesko, UCB (physics) PI
- Stu Loken, LBNL (E+O)
- Hitoshi Murayama, UCB (physics theory, neutrinos)
- Tommy Phelps, ORNL (geomicro)
- Bill Roggenthen, SDSM&T (geophysics) coPI
- Ben Sayler, BHSU (E+O)
- Tom Shutt, Case Western (low backgrounds)
- Nikolai Tolich, LBNL (geonus)
- Bruce Vogelaar, Virginia Tech (solar nus)
- Herb Wang, U Wisc. (geology, rock mechanics)
- Joe Wang, LBNL (earth science, geophysics)

Richard DiGennaro, LBNL, Project Manager and Systems Engineer

Mark Laurenti, Mining Engineer

Syd DeVries, Mining Engineer

Dave Snyder, SDSTA Exec. Director

Trudy Severson, SDSTA

SDSTA Engineering and Safety Personnel

Ms. Melissa Barclay & Jeanne Miller

http://neutrino.lbl.gov/Homestake/LOI

http://neutrino.lbl.gov/Homestake/FebWS

http://neutrino.lbl.gov/Homestake

http://homestake.sdsmt.edu/HRB/Refer.htm

http://www.dusel.org

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